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ERROR IN THE JULY-AUGUST NUMBER

Plates XI-XV, in the article on the Moon by Walter H. Haas, should have been inserted facing the back of the book. In this way any confusion in finding the key to the figures on any plate would have been avoided.

When binding the year's numbers together it is suggested that the plates be placed as above stated.

THE JOURNAL

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SPACE, TIME AND MEANING*

By CYRIL G. WATES

THIS is the era of popularized science. No longer is scientific knowledge the exclusive property of a small coterie of experts. The layman reads widely, exhaustively, on every imaginable subject, and if his reading sometimes results in the expression of opinions on matters upon which he is not fully informed, the scientist has only himself to blame. Modern science is heady stuff and the Simple Fellow often finds himself in a state of mental intoxication after a steady diet of food which he has been able only partly to digest.

The present writer, personifying the Simple Fellow, has ventured to express his thoughts on some of the more recondite elements of Astronomy, not because he wishes to pose as an authority but rather in the hope that some answer may be forthcoming to these problems which puzzle him; an answer which will be within the range of his limited intelligence. As Eddington has remarked "if I rashly plunge into deep waters, it is not because I have confidence in my powers of swimming, but to try to show that the water is really deep."

Astronomy is the most catholic of all sciences. Its scope admits no limits save those of infinity, eternity and the grasp of the human intellect. Technically, Astronomy is a tool of almost incredible precision. Its native elements are Space, Time and Matter. It is the handmaid of all the other sciences and, in turn, it claims them as its willing helpers.

*Abridged from a paper read at the Edmonton Centre of the R.A.S.C. on March 12, 1942.

Space

What is Space? This is a question which the Simple Fellow will gladly leave to the philosophers, who will reward the intrepid enquirer with words, words—words! It will be more pertinent to ask "Is Space within the power of the human mind to grasp? Is it conceivable?" What do we mean by the word "conceivable"? It is regrettable that many writers, including scientists (who should know better) use the word in a very loose, even incorrect sense. The following form of statement is only too common:

> Relativity, Atomic Structure, Wavicles, etc., are regarded as inconceivable, but we must remember that the Copernican Theory was inconceivable to his contemporaries. To-day, the idea of a central sun with its attendant planets is taken for granted. Our posterity will regard these other recondite theories in the same light.

This argument is based upon a fallacy. The notion of the earth revolving around the sun was not *inconceivable* to our ancestors; it was simply *unbelievable,* which is quite another matter. We may *conceive* of the most fantastic things, such as the influence of the stars on human affairs. Whether we *believe* them is a matter of credulity, not of intellect.

Consider an equilateral triangle. It has three apexes, equally distant from one another. Add three more similar triangles and we have a tetrahedron, with four apexes all equally spaced. Now take one more step and construct a figure possessing five apexes, equally spaced. We say that this is impossible, but it is more correct to say that it is inconceivable, for the mathematician can construct such a figure in the form of algebraic equations, and can build a whole geometry on this foundation. Nevertheless, it is perfectly safe to assert that our decendants to the millionth generation will be no better able to visualize such a figure than we, their semi-savage ancestors are today!

We are now in a position to understand the question: "Is Space conceivable?" The layman will answer without hesitation in the affirmative. The metaphysician may argue interminably on the subject, but for the Simple Fellow his own consciousness is the final authority. The word "Space" conveys to him an idea as clean cut as "dog" or "house". The problem is not quite so simple, however,

when we begin to speak of different kinds of space; for example, Occupied Space, Empty Space, Finite Space and Infinite Space.

When we consider the question whether these different kinds of space are conceivable, we may return an unqualified affirmative to the first class—Occupied Space. The second class, Empty Space, is a little more doubtful, but perhaps we may say, yes. The interior of a hollow ball from which the air has been evacuated means something to us. Even a universe from which all matter has been eliminated except the observer, retains a certain conceivable reality.

But when we come to deal with Finite and Infinite Space we are forced to return an emphatic "no" to our question. It is safe to say that the human mind cannot conceive of such a thing as finite space. To the philosopher, even to the mathematician, the question "If Space is finite, what lies outside it?" may seem naïve, but it is nevertheless a real and persistent question and, we believe, unanswerable.

Infinite space lies in the category of inconceivable things also. The mind simply refuses to face the thought of space which continues indefinitely. It is not a mere matter of size. Rather there seems to be a deeply rooted instinct that the words "Infinite Space" do not correspond to any actual reality. To the Simple Fellow, the statement that space is infinite is not only inconceivable; it is just not true. Yet he has no alternative to offer. Has the Astronomer, the Physicist, the Mathematician anything to suggest?

Astronomy, as such, is not concerned with the problem of infinite space. We build larger and larger telescopes in order to penetrate more deeply into the far reaches of the material universe, but with no thought that limits may be attained. Modern Physics is largely absorbed in the study of the infinitely small. It is to the Mathematicians that we must turn for light on the infinitely great. It remains to be seen whether the light they have produced is the clear ray of knowledge, or the will-o'-the-wisp of illusion.

What is Mathematics? The dictionaries tells us that it is the science of space and number, but Dr. C. J. Keyser, in a keenly analytical essay, "The Meaning of Mathematics", points out that mathematics is not a science, but a unique way of thinking, and that space and number are only two of the many applications of mathematics. Dr. Keyser summarizes as follows:

> Thus we are led to see and to say that Science has for its characteristic aim the establishment of *categorical propositions* in answer to questions about the actual world, and that, in sharpest contrast therewith, Mathematics has for its characteristic aim to establish *hypothetical propositions* in answer to questions regarding the Logically Possible.[1]

The italics are mine. If we accept Dr. Keyser's thesis, there is nothing contradictory in the statement that Mathematics, which traditionally had its origin in the Harp of Pythagoras, has a closer relationship with music than it has with science. The student of mathematics, like the student of music, devotes himself to the study of Forms, whether it be the form of the binomial theorem or the form of the chord of the dominant seventh. He learns to bring these forms into logical relationship with each other and ultimately finds his mind enriched to the point where he may produce a symphony or a Theory of Relativity.

Every Mathematician, whether he admits it or not, is thrilled and inspired by the aesthetic beauty of the processes by which he arrives at his conclusions. Those of us whose mathematics was confined to the strictly formal propositions of elementary algebra, geometry and trigonometry can have but the vaguest conception of the complete freedom with which the mind of the skilled mathematician plays over the concepts of which he is master, as the hands of the musician play over the console of the organ, creating, selecting, combining into what is, for each of them, a complete work of art.

After this digression, we are ready to see where the Mathematician's concept of space will lead us. His latest answer to the question "What is Space" is very simple: "Space is Finite, but Unbounded." In other words, there is only just so much space, but it has no limits. This amazing conclusion has been reached by the application of the laws of Relativity. What does it mean? If you ask the Mathematician this question, he will probably look at you pityingly and explain that it does not mean anything; that it represents Reality, which is, of course, beyond the power of the human mind to apprehend. Perhaps he may tell you the fable of the Flatlanders, those two-dimensional beings who roam over the surface of a huge sphere, and whose two-

[1] "Mathematics and the Question of the Cosmic Mind," Cassius Jackson Keyser.

dimensional space is, therefore, strictly finite but unbounded. The fact that the interior of such a sphere contains an infinite amount of two-dimensional space seems to the Simple Fellow to destroy the aptness of the analogy!

J. W. N. Sullivan, speaking of the mathematician's finite, unbounded and expanding space (because, just for good measure, space is supposed to be getting bigger all the time), has this to say:

> Not all men, not even all scientific men, are mathematicians, and this new stage that physical science has reached has taken it distressingly far from ordinary comprehension. Yet something of the sort was to be expected. Why should we suppose that the fundamental processes of nature should resemble processes made familiar to us by ordinary experience?

The Simple Fellow will say, why not? Mr. Sullivan continues:

> The present state of affairs is, perhaps, even more disastrous for the writer who wishes to present modern scientific ideas to the layman. For when the layman asks for an explanation, he is saying, nine time out of ten, show me a picture.[2]

Since none of us receives any impressions except through the medium of the senses, are not laymen justified in the assumption that all ideas must necessarily be comprehensible to these senses? The mind of the mathematician differs from the mind of the layman in degree, not in kind. It appears to the Simple Fellow that the mathematician is extraordinarily arbitrary in his choice of what shall be significant and what meaningless. He agrees that x^4 has no parallel in the physical world, but demands that equations which describe a finite but unbounded universe shall be accepted as reality.

The fact that relativity equations receive support from certain hitherto unexplained phenomena has no bearing upon the matter. In fact, this evidence is self-destructive. With one breath the mathematician declares that his equations are incapable of reduction to the plane of the senses. With the next he adduces phenomena which *are* within the reach of the senses as proof of his transcendental theories.

Sullivan speaks of "the straightfordward consequence of the fact that we live in a non-Euclidean universe". How can there be such a thing as a "straightforward consequence" of a theory which is completely transcendental; that is, beyond the scope of our senses?

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[2] "The Limitations of Science", J. W. N. Sullivan.

Sir James Jeans correctly states that we cannot claim to possess knowledge which we cannot explain to another person with a brain similar to our own. He comments on the fact that in modern theory we are faced with concepts which do not admit of explanation in terms of the senses; and finally concludes that no new concept can be acquired except by combining concepts already existing in the mind.

Is it any wonder that the Simple Fellow tends to lay undue stress on definitions when he remembers that a "concept" is something imagined, and that "imagination" is derived from *imaginari*, meaning to form or make a picture?

We are told that the ether is a naïve and discredited notion. In its place, we are offered the space-time continuum. It is a dubious advantage that the continuum is meaningless except as a set of mathematical equations, whereas the ether, with all its faults, bore some semblance of reality. Newton pointed out that action-at-a-distance is unthinkable and, indeed, he had no explanation of the force of gravity except to suggest that it is "the Will of God." In what way the new geometry cuts the Gordian Knot of action-at-distance is not apparent to the ordinary man. Our old friend Diogenes Teufelsdröckh said "Nothing can act save where it is? With all my heart! But where is it?"[3]

The Simple Fellow finds nothing more unthinkable in action-at-a-distance than in the concept of potential energy. A steel ball exhibits the same properties, chemical and physical, whether it is at rest or on board a train travelling at high speed, yet its properties when brought into contact with a stationary object are quite different. Potential energy is a name, as action-at-a-distance is a name for things we frankly do not understand, and to explain the latter by the new geomerty instead of by strains in the ether or by Newton's "Will of God" is simply changing the question mark of the nineteenth century to the exclamation mark of the twentieth. This certainly seems to be one of these cases in which there is an elusive factor missing from our mode of thinking.

While on the subject of gravitation, the layman will find food for

[3]Carlisle, "Sartor Resartus".

thought in the alleged difficulty of conceiving of gravitation as an instantaneous attraction between two bodies, but since there is no practicable method by which matter may be either created or destroyed, how can we tell that the transmission of gravity is independent of time? Like the famous case of fingers and forks, all the matter in the universe was here before we arrived!

Returning to the theory of expanding space, which is so prominent in modern astronomical thought, Sullivan says:

> Nothing is gained by trying to picture this space. The attempt to do so leads to such questions as 'If space is expanding, what is it expanding into?' This question *presupposes* a picture, and is therefore irrelevant to the mathematician.

In other words, the mathematician will play the game according to his own rules or not at all! Yet, what possible objection can be taken to the question "What is space expanding into?" It makes no difference whether we consider the space of the man in the street, or the transcendental space of the mathematician. To both space must be something, and if that "something" is expanding, it must necessarily be larger to-day than yesterday. And since the additional "something" was not a part of yesterday's "something", it must have been pre-existent. The fly in the ointment is the word "finite". Euclid's law that the whole is greater than any of its parts does not hold true for infinites, but in asserting that space is finite, the mathematician tacitly admits that Euclid's law applies to space of any form which can be represented in a model or an equation.

In leaving the subject of Space, the writer wishes to remove any impression he may have given that the Simple Fellow is lacking in respect for Mathematics. On the contrary, he regards mathematics as the greatest monument to the power of the human intellect which has ever been erected. He bows in humility before the mighty structure which has its foundations in Pythagoras and its cap-stone in Einstein. To change the metaphor, the union of Science and Mathematics has brought forth a numerous progeny to bless mankind. But even the happiest and most prolific marriages sometimes bring forth a monstrosity!

There is nothing recondite in either mathematics or science, but the layman sometimes feels that somewhere in the ancestry of one

or the other of this pair there has been a bar sinister; an unholy alliance with mysticism or superstition which, following strictly Mendelian laws, is appearing in the present generation.

Time

Amongst the pigments with which the Astronomer is striving to paint a reasonably true picture of the universe, there is none so familiar as Time; yet in spite of this seeming familiarity it is an interesting and revealing discipline to spend some time in attempting to define Time. The dictionaries will not help much, for the definitions we shall find in them are little more than synonyms such as "the elapsed interval between two events." In that readable and fascinating work, "The Book of Time," G. L. Kaufman states that is its impossible to define Time. Simply because the word impossible is always provocative, we will let the Simple Fellow try his hand at the job.

There is a group of substances known to chemists as Catalysts. In industrial chemistry a catalyst is something which is an essential adjunct to a process or reaction, from which the catalyst emerges unchanged. An example is the process of making shortening from vegetable oil. Hydrogen gas bubbles through the oil which contains finely powdered nickel. The hydrogen combines with the oil to form a heavy fat, but the nickel emerges unchanged and may be used again. It is a catalyst.

By analogy, then, "Time is a Catalyst which, itself unchanged, is an essential factor in all physical changes."

It would be vain to pretend that this definition helps us to visualize Time, as we visualize a tree or a house, but at least it seems to satisfy our observations. For example, an astronomer has two photographs of a double star. He finds that the plates indicate a change of relative position. He knows that certain forces have operated to produce the change, but he also knows that, over and above these forces, some other factor has been in operation. This factor is the catalyst, Time.

To the Astronomer, time is of vital importance as a measurable factor in the study of change in the universe. All the astronomer's work is concerned with short periods of time. Even the development of the spiral nebulae takes place in time that is probably insignificant as compared with the life-history of the universe as a whole.

is the result of differences of level. It is the difference of level between the reservoir and the sea which supplies energy to the turbines. It is the difference of electrical level between the terminals of the generator which lights the street lamps. It is the difference of chemical level in an explosive which enables us to avail ourselves of its molecular energy to destroy our enemies.

If the heat of the sun were suddenly cut off, all the waters of the earth would drain into the sea and remain there forever. That water would still possess tremendous potential energy, since it would be subject to gravitation, but it would be *unavailable* energy. Of course, the water would freeze, but we are, for the sake of discussion, disregarding that possibility. The point is that, with the energy of the sun cut off, the earth would become a dead world like the moon. This energy-death is quite aside from the fact that all life would cease. It means complete absence of change, which takes place only as the result of differences of energy-level.

Physicists call this state of energy-death "Maximum Entropy" and the operation of entropy is governed by the Second Law of Thermodynamics. Entropy means the progress of change in time, the processes by which energy becomes unavailable for performing work.

The levelling off of energy in our reservoir system, the levelling off of all energy on a sunless earth, are simply examples in the small of what is believed to be taking place throughout the universe. In a sense, the universe is supposed to be running down, and astronomers look forward to a time, immensely distant, when all the tremendous energy now displayed by countless suns and systems will be reduced to a dead level of unavailability. Entropy will be 100 per cent. complete. The universe will be static, unchanging and, with the cessation of change, Time, the catalyst, will cease also, or at least become meaningless.

Here is a doctrine of absolute despair! Is there no ray of hope? Must we submit tamely to a destiny which holds forth nothing better than the black shadow of entropy engulfing all the wonder and glory we see about us?

The Simple Fellow may find some comfort in the words of A. N. Whitehead:

> The moral to be drawn from a general survey of the physical universe is . . .

There is little or no disagreement among astronomers with regard to these short-time phenomena, but the case is quite different when the concepts of "beginning" and " ending" enter the fields of thought. Is there any evidence to show that the universe had a beginning? Do we find anything which leads us to believe that the universe will come to an end?

To the early astronomers, the thought that time is infinite was assumed as a foregone conclusion. Eternal time, like infinite space, were accepted as realities beyond the scope of the human mind to grasp. Modern science has, to a large extent, rejected these ideas as belonging rather to the realm of metaphysics than to that of serious reasoning. The expanding universe sets a definite limit to the extension of time into the past, while the Second Law of Thermodynamics sets a limit to time in the future. This law is not easy for the Simple Fellow to understand, but he makes the attempt.

The whole universe may be visualized as a storehouse of energy. Energy is that property of matter which enables it to perform work. Work involves the ideas of time and change. For example, a reservoir full of water possesses energy of position, but it performs no work until the water is released so that it can flow to a lower level, turning the wheels of turbines on its way. If these turbines drive generators, and if, in turn, the current from the generators is used to light a city, practically the entire energy of the reservoir passes away into space in the form of light. This light, itself a form of radiant energy, is, so far as we know, forever lost. At least, we know of no way in which it can ever become available to perform further work.

When the reservoir is empty the turbines will stop and the water, returning to the sea, is unavailable as a source of work. It is true that the reservoir is refilled by rain, but this is done only at the expense of additional energy drawn from the sun, whose rays evaporate sea water and raise it to a level at which it can fall as rain. Thus, the small fraction of the sun's rays which is intercepted by the sea suffers a detour involving evaporation, clouds, rain, rivers, reservoir, turbines, generators, wires, transformers, lamps and, finally light; in which form it passes out into space and is lost as a source of available energy.

That word "available" is the crux of the whole matter. All work

that we have omitted some general counter agency. This counter agency is too vast and diffusive for our direct observation. We may acquire such power as the result of some advance. But, at present, as we survey the physical cosmos, there is no direct intuition of the counter-agency to which it owed it possibility of existence as a wasting, finite organization.[4]

And Sullivan says:

It is highly probable that we are here faced with a real limitation of the scientific scheme. The analysis has not been sufficiently discriminating. It may be that the notion of time is too meagre an abstraction. Or it may be that the scientific scheme has omitted some essential element.

If the Simple Fellow trusts to his intuition, and to the past history of science, he will heartily agree that what these writers say is entirely probable. In that monumental work, "The Golden Bough", Sir James Frazer shows an acute understanding of the layman's predicament. He says:

The history of thought should warn us against concluding that because the theory of the world is the best that has yet been formulated, it is necessarily complete or final. We must remember that, at bottom, the generalizations of science or, in common parlance, the Laws of Nature, are merely hypotheses devised to explain that ever-shifting phantasmagoria of thought which we dignify with the high-sounding names of the World and the Universe. . . . In the ages to come, man may be able to predict, perhaps even to control, the wayward course of the winds and clouds, but hardly will his puny hands have strength to speed afresh our slackening planet in its orbit, or rekindle the dying fire of the sun. Yet the philosopher who trembles at the thought of such distant catastrophies may console himself with the reflection that these gloomy apprehensions, like the earth and the sun themselves, are only part of that unsubstantial world which thought has conjured up out of the void, and that the phantoms which the subtle enchantress has evoked today, she may ban tomorrow. They too, like so much that to common eyes seems solid, may melt into air, thin air.[5]

Meaning

Finally, what is the meaning of this universe of Time and Space; or has it indeed no meaning at all? One fact may be asserted with complete confidence; that the question itself, in the form in which it has been stated, is itself absolutely meaningless.

"Has the Universe any Purpose?" is a senseless question like "Has

[4]A. N. Whitehead, "Science and the Modern World."

[5]Sir James Frazer, "The Golden Bough."

the Sun any Distance?" Purpose, like Distance, is relative. Both sentences presuppose a second question. "What is the object from which the sun's distance is desired?" and "What is the object in relation to which we desire to ascertain the purpose of the universe?"

Since Man, as a material collection of atoms and molecules, is a part of the universe he inhabits, it cannot be Man, so regarded, in relation to which the universe has a purpose. Obviously, there can be no meaningful relation between the material universe, including Man, and anything save some immaterial object; using "immaterial" in the sense "not subject to the laws that govern matter". We know of no such object save the Human Mind. Has man an immaterial mind? The followers of the now discredited theory of Behaviorism would approve the words of Bertrand Russell on this subject:

> That man is the product of causes which had no prevision of the end they were achieving; that his origin, his growth, his hopes and fears, his loves and beliefs, are but the outcome of accidental collocations of atoms; that no fire, no heroism, no intensity of thought and feeling, can preserve an individual life beyond the grave; that all the labours of the ages, all the devotion, all the inspiration, all the noonday brightness of human genius, are destined to extinction in the vast death of the solar system, and that the whole temple of man's achievement must inevitably be buried beneath the debris of a universe in ruins—all these things, if not quite beyond dispute, are yet so nearly certain that no philosophy which rejects them can hope to stand. Only on the firm foundation of unyielding dispair can the soul's habitation be safely built.

If this be true, then indeed the universe has no meaning for the mind, and we have no recourse but to accept whole-heartedly the hopeless cry of the Tentmaker:

> And this inverted bowl we call the sky,
> Whereunder, crawling cooped, we live and die—
> Lift not your hands to it for help, for it
> As impotently moves as you and I.

The Simple Fellow will prefer the utter simplicity of Poincaré's epigram—"Thought is only a flash of light between two eternities of darkness, but thought is all there is!" Nevertheless, his browsings in the literature of modern science leave him with the impression that it is a point of honour among scientists to disbelieve in the existence of an immaterial mind. As the orthodox clergy were required to subscribe to the Thirty-Nine Articles, so the modern physicist, and even

the modern biologist, seems to feel that he must ignore the existence of a mind.

So far as the physicist and astronomer are concerned, this attitude is not illogical. They deal with the world of matter and radiation. His ideal observer is, and must be, a mindless automaton; a machine for receiving impressions. J. W. Dunne remarks that

> physics is a science which has been expressly designed to study, not the universe, but the things which would supposedly remain in that universe if we were to abstract therefrom every effect of a purely sensory character. . . . . But these remnants are the most obtrusive things in the universe. So obtrusive that they produce the effect of a vast external world of flaming lights and colors, pungent scents and clamorous, tumultuous sounds. Collectively they bulk into a most amazing tempest of sharply differentiated phenomena. And it is a tempest which remains to be considered *after* physics has completed its say.[6]

Let us assume, then, that the Simple Fellow has some justification for his instinctive belief that there is a mind apart from the brain which is its instrument of expression. There still remains the difficult question of meaning and purpose. Sullivan says:

> Purpose is not yet a scientific notion. It is not employed in the physical or chemical sciences, and the majority of biologists or, at least, of physiologists, are reluctant to introduce any ideas which have not been found necessary in these sciences.

Whitehead is gently satirical in dealing with the subject:

> The problem is to understand the operations of an animal body. The existence of a problem is not even acknowledged. It is vehemently denied. Many a scientist has patiently designed experiments for the purpose of substantiating his belief that animal operations are motivated by no purposes. He has, perhaps, spent his spare time in writing articles to prove that human beings are as other animals, so that 'purpose' is a category irrelevant for the explanation of their bodily activities, his own activities included. Scientists animated by the purpose of proving that they are purposeless constitute an interesting subject for study!

The subject of evolution is closely linked with that of purpose. The layman of today has been brought up to regard evolution as one of the basic facts of science, yet he is conscious of a vague feeling of discontent. To attribute such formations as the ossicles of the middle ear or the semicircular canals to evolutionary causes alone seems to require an almost childlike credulity. A watch in process of assembly

[6] J. W. Dunne, "An Experiment with Time."

does not work better and better as the various parts are put in place. It starts to operate suddenly when the last wheel is installed, and not until then. The analogy is obvious.

Sullivan analyses the relationship of evolution and purpose in these words:

> Again and again we have the feeling that the primary concepts used by biologists are inadequate to their most important problems. The theory of Natural Selection as an explanation of evolution does not in the least explain the most obvious fact of the whole process, that is, the upward tendency of living things. . . . We have the impression that it is only by an extraordinary act of faith that biologists can suppose that the actual progress of life can be explained in the terms they adopt.

J. B. S. Haldane also feels this divine discontent with evolution in its present form, and refers to Royce's concept of a so-called "emergent"; a mind with a vast time-scale which controls the processes of evolution. He says:

> My suspicion of some unknown type of being associated with evolution is my tribute to its beauty and to that inexhaustible queerness which is the main characteristic of the universe.

When all is said and done, the Simple Fellow, even if he delves rather deeply into scientific literature, will continue to cling to his instinctive belief that the material universe has a purpose, and that its purpose is to provide a framework for the development of intelligent life. He is thankful to the astronomers for having left him the possibility of life on other planets, even though such abodes of Mind are far less numerous than they were assumed to be a century ago, but it would not alter his stubborn convictions on the subject if he knew that the earth were the sole abode of life.

The argument of disparity of size leaves him quite indifferent. He sees nothing in the least unreasonable that a universe containing countless billions of suns should have been brought into existence simply to provide an environment for a few infinitesimal inhabited worlds. He holds to the idea that purpose and meaning have no significance except as a relationship between mind and matter. The germ cell is invisibly small compared with the mature animal, yet neither has any meaning in relationship to the other.

Our Simple Fellow has the most tremendous admiration for the

scientist and the mathematician, and an almost childlike faith in their powers, but he has not forgotten the fate of Phlogiston, the Ptolemaic Theory and a hundred other products of mature human intelligence. He applies to each new theory of science, the words of wise old Omar:

> When you and I behind the veil are past,
> Oh, but the long, long time the world shall last,
> Which of our coming and departure heeds
> As the sea's self should heed the pebble cast.

The Simple Fellow is only one of the great army of kindergarten students, shouting opinions at the calculus class, so he will call upon Sullivan to speak the peroration for him:

> The apparent agreement between calculation and experiment . . . seems in some sense to be illusory. It is very difficult to avoid the conclusion that the experiments have not yet received their right interpretation. We feel that our difficulties can only be resolved by man's imagination rising to the task of constructing radically new concepts. We are required to see the universe with new eyes, and it is because it makes such demands, and also holds out the promise of realizing them, that the study of science is so supremely worth while.

And this, with special application to the science of Astronomy, is, we believe, entirely in accord with the simple thoughts of a Simple Fellow.

(Author's Note: This paper was prepared for oral delivery rather than for publication, and I have not found it possible to trace the source of all quotations. For any errors in references or wording, I tender my apologies to their authors.)

THE NATURE OF THE SOLAR CORONA

By William Petrie

RECENTLY, one of the outstanding astrophysical problems has been solved, namely, the origin of the bright lines that appear in the spectrum of the solar corona. Perhaps the most fascinating of all solar phenomena, the corona has long attracted the attention of astronomers and physicists.

The story of the study of the coronal spectrum is an interesting one, and may be said to have started with the eclipse of 1869, when Young and Harkness independently discovered a bright line in the green region of the spectrum. Young erroneously identified this line with that of iron at wave-length 5316.8A. In view of the difficulties of visual observations during an eclipse, it is not surprising that this error persisted until 1898, when Lockyer photographed the coronal spectrum and found the wave-length of the green line to be 5303.7A.

For twenty-four years after Young's discovery, very little was added to the knowledge of the coronal spectrum. During this period many lines, originally listed as coronal, were later deleted when it was found they were due to prominences and the chromosphere. Of all the lines given, possibly only two arose from the corona, those at λ4086 and λ4232.8. Succeeding eclipses revealed additional known or suspected lines, and the number had grown to forty by 1918. Since that time, however, many have been discarded, and the list has shrunk in number to twenty-three. The justification for dropping certain of these lines might be questioned. It is now definitely established that the coronal lines vary in intensity from eclipse to eclipse; on occasions some have even been absent from the spectrum and then have reappeared at a later date. The fact that a line has been recorded at only one eclipse is not sufficient justification for discarding it as non-coronal.

While the lines were being discovered and their wave-lengths determined, the interesting fact appeared that they could not be identified with any known element. The mysterious substance producing these lines was named "coronium," and for some time scientists believed that its identification would mean the discovery of a new element. In recent years, however, this theory was discarded, par-

ticularly when "nebulium," the element supposed to be responsible for certain bright lines found in gaseous nebulae, turned out to be oxygen and nitrogen in an unusual state. Scientists then expected that "coronium" was a familiar element in an unfamiliar form because of the extreme conditions existing in the corona.

Spectroscopists tackled the identification problem with great enthusiasm but with little success. With the development of a new method of analysis, namely, wave mechanics, it seemed certain that the element or elements producing these bright coronal lines would be "exposed," but even this powerful tool failed to give the solution.

At first thought it might seem surprising that until a few months ago, knowledge of the subject had not increased in proportion to the number of intervening years. It is true that other bright lines were found and attributed to the corona, and a study of these during various eclipses revealed several facts regarding the physical state of "coronium" and its distribution about the sun.

1. The distribution was found to be non-uniform and seemed more abundant in the vicinity of prominences.

2. Dissimilarities in the structure of the lines suggested that they arose from atoms in different degrees of excitation.

3. From the appearance of the lines, it was evident that the producing atoms were in a highly energized state.

The sum total of these facts, however, does not give a very complete picture of the physical state of the corona. Since the entire time which has been spent in photographing the spectrum amounts to approximately one hour, the slow advance of the subject is perhaps understandable.

Several months ago, a very exciting communication from the Swedish physicist Bengt Edlén offered an identification for "coronium." It is now apparent why the solution was so long in appearing. Astronomers have been too conservative. So startling was Edlén's proposal that he himself was rather hesitant about announcing it, and in fact did not do so for some time. He suggested that the coronal line emission was due to certain metals, chiefly iron, in a highly ionized condition. He found that the strongest line arose from Fe XIV, while the three next strongest were due to Fe XIII. It was previously observed by Grotrian that the lines $\lambda\lambda$6374 and 7892 could be attributed to Fe X and Fe XI, respectively, and it is impor-

tant that these six lines contribute more than ninety per cent to the total line emission. Edlén also found that the origin of some of the fainter lines was highly ionized nickel and calcium.

There are data which support this identification.

(i) The non-appearance of lines from Fe VIII, IX, XV, XVI, XVII can be explained by wave-mechanical considerations, while Fe XII produces no lines in the observable part of the spectrum.

(ii) The relative intensities of the iron to nickel lines is roughly ten to one, which suggests that iron is ten times more abundant than nickel. This figure agrees with the latest determinations of the relative abundances.

(iii) Slitless spectrograms provide a means of classifying coronal lines according to the degree of excitation of the producing atoms, and Edlén's identification agrees well with the classification.

If Edlén's theory is correct, the conclusions which must be drawn are startling. Fe XIV has thirteen outer electrons removed, and the energy required for this process is enormous, indicating a temperature for the corona of over two million degrees.

There are strong indications that the temperature of at least certain parts of the solar atmosphere is higher than 6000°, the figure often quoted.

(i) The spectra of prominences and the chromosphere photographed during a total solar eclipse show intense lines of neutral and ionized helium, which could be produced only if the temperature were of the order of 25,000°.

(ii) The electron density in the upper atmosphere of the earth demands a greater amount of ultra-violet light than that produced at 6000°.

(iii) If the mechanism of prominence support is the absorption of ultra-violet light, then the temperature must be at least 12,000°.

But here are indications of a coronal temperature in the millions of degrees! How can such a situation exist, that the temperature in the corona at a distance of 300,000 miles from the sun's surface is much greater than at the surface? Dr. D. H. Menzel of the Harvard College Observatory suggests that the sun has "leaks," and that the

high temperature material from deep inside the surface escapes. This might explain the phenomenon of coronal prominences. Photographs of the solar surface taken by means of the spectroheliograph in light of a particular wave-length, show streamers of material apparently condensing from the corona and falling towards the photosphere. As the highly ionized coronal material cooled, it would capture electrons and finally emit radiation of the wave-length utilized by the spectroheliograph. At this stage it would become visible and seem to condense from the corona.

It should be mentioned that it is difficult to explain certain observations on the basis of Edlén's theory. Waldmeier, at a station in the Swiss Alps, has found the green coronal line to appear double at certain times when it is very intense. He suggests that the doubling is a case of "self-reversal," that is, a narrow absorption line is formed over a broad emission line, producing a spurious doubling effect. A phenomenon of this sort can exist only if the number of atoms is great, since the transition probabilities between states involved in the production of coronal lines are exceedingly small. However, the doubling may not be due to "self-reversal," and many more observations are needed.

One might expect that lines due to highly ionized titanium would appear in the coronal spectrum. Ti IX has three observable lines at λ3923, λ4200, λ4705, and the ionization potential is of the order of 200 volts, sufficiently high for the Edlén mechanism to take place. Swings and Struve have observed the line at λ3923 in C I Cygni. The absence of titanium lines may simply be due to the fact that too little of this element is present in the sun. The lines that Edlén associated with calcium are weak, and since titanium is less abundant even weaker lines would result.

Interest in coronal problems is by no means at an end even if the identification of the line emission is correct. The corona consists of three parts, the outer giving rise to the Fraunhofer spectrum, the intermediate to the continuous spectrum, and the inner to the bright lines. The origin of the Fraunhofer and the continuous spectrum has been and remains a problem. The absorption lines cannot be attributed to electron scattering because they do not have sufficient width. The temperature existing in the corona would produce such an electron velocity that the lines would be greatly broadened. On

the other hand these absorption lines cannot be produced by particles of atomic dimensions, since such scattering should exhibit the Rayleigh blue while the corona is white.

Because of these difficulties, Minnaert suggested that electron scattering produces the continuous spectrum, while the Fraunhofer lines arise from scattering of light by atoms or ions. However, if this were so, the degree of polarization of the coronal light should increase from red to blue, and experiments have shown that it does not. An alternative theory was proposed by Grotrian, who assumed that electron scattering produced the continuous spectrum while the absorption lines were formed by scattering of light from dust particles. One obvious difficulty is to explain why a dust particle would not volatilize at the high temperatures existing in the corona.

A recent investigation[1] by Dr. Menzel and the writer at the Harvard College Observatory has revealed some twelve new coronal lines. The material was obtained by the Harvard—Massachusettes Institute of Technology eclipse expedition to Siberia in 1936, and consisted of both slitless and moving film spectrograms. One of the latter was remarkable in that it showed six new lines, and the wavelengths were obtained by running the spectrogram through the wavelength measuring machine in the spectroscopic laboratory at the Massachusetts Institute of Technology. In spite of the dangers of wrong identification, the authors feel that these lines are truly coronal in origin.

An attack similar to that used by Edlén may reveal the identity of these lines, since there are other atoms in highly excited states which have not yet been investigated. Edlén's work constitutes a real advance in the study of the corona, which is most encouraging after the somewhat stagnant condition of the problem, but much more work both observational and theoretical must be conducted before the nature of the corona is thoroughly understood.

[1]Not yet published.

DOES ANYTHING EVER HAPPEN ON THE MOON?

By Walter H. Haas

(*Continued from page 272*)

Some Observations of Colours on the Moon

Lunar colours have been detected by such skilled selenographers as Gruithuisen, Maedler, Klein, Maw, Birt, Schmidt, and Pickering. The hue apparently seen most is a high-sun greenishness to some of the *maria*, notably Crisium, Serenitatis, and Humorum;[15, 71, 78] but the vagueness of even this tint is evidenced by Goodacre's remark:[15] "These green tints, referred to, must be very faint and fugitive, as the writer has never seen them." Molesworth, Goodacre, and others have observed a bluish glare on the brilliant east wall of Aristarchus just after sunrise;[15] and Schmidt has detected a violet hue near this crater,[78] which Klein confirms[33] but Pickering doubts.[50] A green near Schroeter's Valley was very striking to Gruithuisen in 1824 and to Klein in 1881(?)[33] but was not visible to Pickering in 1902,[50] and I have never noticed it in the course of several hundred observations of detail in this vicinity. Birt found a greenish tint to obliquely illuminated *maria*.[78] Goodacre writes of Lichtenberg:[15] "Maedler once saw a reddish tint on the surface near the western wall which has not been seen by any subsequent observer." After he had been studying the moon for more than 30 years, Pickering asserted that the high-sun dark areas he observed are sometimes purplish and that some greys are browner than others.[63] In the report of 1934-7 observations by Kaiser's *Arbeitsgruppe fuer Mondbeobachtungen*[32] we find especially interesting the green in Serenitatis, an often conspicuous but frequently absent brown in Plato, and a cycle of colour-changes in Ptolemy from light grey to olive green near 35° and thence to a greenish or yellowish tone between 110° and 150°. In every lunation from December 1937 to April 1938, Barker and Fox observed (and agreed well upon) a brown hue on the west wall, and at the west end of the floor, of Plato.[3] They found variations both in intensity and in the region affected but apparently did not attempt to relate their results to colongitude.

The monochromatic lunar photography of Wood[81] and Wright,[83] among others, has opened a very promising field for study. The most conspicuous of a number of differences between extreme red and ultra-violet photographs is the greatly increased darkness of an area north and east of Aristarchus on the latter; reasoning by analogous effects on terrestrial rocks, Wood concluded that this region represents a deposit of sulphur.[81]

Wilson writes that he has secured tricolour photographs of the moon with an F/8 aluminized 12-inch mirror. Printed in colour, these reveal near full moon an olive green in Imbrium and part of Serenitatis and and distinct brownish tints. Wilson suggests that these colours are due to the fact that near full moon the paths of both incident and reflected sunlight fall near the line of sight whereas at other phases they do not both do so.

Colour Studies by Our Group

There follows a region-by-region account of the visual colour observations we have made. Once more, rarely observed objects of little interest, including all the chocolate-brown hues I suspected in shadows in 1935-6, will be omitted. These shadow-browns are probably subjective with me; to be sure, Goodacre observed in some shadows a chocolate-coloured margin, which he considered a penumbral effect.[15]

1. *Aristarchus.* $\lambda -47°$, $\beta +24°$. Sunrise 47°, noon 137°, sunset 227°. 1 observation.

On December 27, 1939, at 106° Barcroft noted a slight bluish tinge on the still brilliant east wall.

2. *Atlas.* $\lambda +44°$, $\beta +47°$. Sunrise 316°, noon 46°, sunset 136°. 23 observations.

I find in the darker portions of the floor a slight brownish hue, perhaps very slightly tinted with purple, changing little all lunation. Cyrus could only suspect the brown, and a Mount Union student did not see this colour at all.

3. *Billy.* $\lambda -50°$, $\beta -40°$. Sunrise 50°, noon 140°, sunset 230°. 30 observations.

The darker parts look somewhat brownish to me, the colour varying little all lunation.

4. *Crisium, Mare.* $\lambda +60°$, $\beta +16°$. Sunrise 300°, noon 30°, sunset 120°. 62 observations.

This plain is distinctly greenish at sunrise; the hue fades steadily and finally vanishes near 0°. The colour is grey from then until about 100°. A greenishness

now reappears and becomes more intense toward sunset but never equals the colour at 300°-315°. The green colour (which, when present, is seen best in a very clear sky) has been observed by five former Mount Union students, including me; but four more students have seen grey under conditions favourable for detecting green, as Brockmeyer also has done. McLeod reports that Crisium darkens greatly when viewed through a red filter, as a green area would do; and Cyrus states that in the course of other programmes he has "often noticed the green in Mare Crisium."

On June 22, 1936, at 301° Roth and Weldy each noted reddish spots near the south end of the *mare*.

5. *Cruger*. $\lambda -67°$, $\beta -17°$. Sunrise 67°, noon 157°, sunset 247°. 25 observations.

I have found the darker portions to be somewhat brownish all lunation.

6. *Endymion*. $\lambda +56°$, $\beta +53°$. Sunrise 304°, noon 34°, sunset 124°. 72 observations.

At sunrise the floor is very dark and may be brown, but Roth does not confirm me about this hue. Cyrus and I agree that near 335° most of the floor is grey and that there is a brownish area under the northeast wall, an aspect also seen by a Mount Union student at 356°. From 350° to 90° the east part of the floor is grey tinged by brown; the west part, grey perhaps tinged by green. After 90° the brown vanishes; and the green grows stronger, often being striking subsequent to 115°. The evidence that this evening green varies in different lunations is good; and I record below all my observations after 105°, relating them to the sun's height *h*.

TABLE VII.—COLOUR OF ENDYMION, 105°-121°

Date	*h*	*Telescope**	*Colour*	*Remarks*
Oct. 2, 1936	9°.8	10-in. rr.	greenish or brownish	uncertain of hue.
Oct. 2, 1936	9.0	10-in. rr.	greenish grey	green not vivid.
July 21, 1940	8.7	6-in. rl.	definitely green	
June 25, 1937	8.6	10-in. rr.	grey	slight haze
Sept. 18, 1940	8.0	6-in. rl.	greenish grey	
Oct. 21, 1937	7.9	10-in. rr.	green	passing clouds
July 6, 1936	6.8	10-in. rr.	greenish	
Aug. 20, 1940	6.0	6-in. rl.	greenish grey	green not pronounced.
June 22, 1940	5.5	6-in. rl.	brownish grey	
Aug. 20, 1940	5.5	6-in. rl.	greenish grey	perhaps greener than with *h* 6°.0.
Sept. 22, 1937	5.0	10-in. rr.	strong green	
Aug. 20, 1940	4.4	6-in. rl.	distinctly greenish	perhaps greener than with *h* 6°.0 or 5°.5.
Aug. 20, 1940	4.1	6-in. rl.	green	green growing stronger
Mar. 26, 1940	4.1	12-in. rr.	brownish grey	certainly no appreciable green

TABLE VII—(*Continued*)

Date	*h*	*Telescope**	*Colour*	*Remarks*
Apr. 9, 1936	4.0	10-in. rr.	very green	first observation.
July 25, 1937	3.9	10-in. rr.	green	
June 15, 1938	3.6	10-in. rr.	vivid green	by far greenest area on moon.
Oct. 11, 1938	3.5	9-in. rr.	greenish	
Aug. 13, 1938	3.4	6-in. rl.**	greenish	hue not vivid.
July 25, 1937	3.3	10-in. rr.	brown	slight haze
Apr. 28, 1937	2.6	10-in. rr.	very brown	

*Same abbreviations as in Table III.

**Not the 6-in. rl. used in 1940.

7. *Furnerius.* $\lambda+60°, \beta-36°$. Sunrise 300°, noon 30°, sunset 120°. 43 observations.

On May 24, 1936, at 306° Roth and I agreed that the floor was brownish in the southeast quadrant and greenish elsewhere, a result in harmony with other early observations. The floor is subsequently sensibly grey with the exceptions of probable brownish portions between 340° and 10°, a purplish grey or brownish grey band joining the centre and the south rim after 65°, and probable dark purple spots at the foot of the west wall just before sunset.

8. *Grimaldi.* $\lambda-67°, \beta-6°$. Sunrise 67°, noon 157°, sunset 247°. 184 observations.

When I studied Pickering's original observations of the colour on the floor I was puzzled to discover that observations in the same lunation usually agreed well but that those in different lunations showed so much variation that no cycle of colour-changes could be determined.

The work of our group establishes that the south, the east, and the west edge of Grimaldi are brownish grey with a possible tinge of purple from 80° to 230° but gives no evidence about the behaviour of the greenish grey hue on the floor, except to show that this latter colour is not always the same. The green almost certainly varies irregularly from lunation to lunation. For example, in 1937 I called the floor "strong green" on September 23 at 129° but only "slightly greenish" on April 29 at 134° under identical conditions of observation. Likewise, in 1938 at 234° I observed the floor to be "strongly green" on March 28 but merely "greenish grey" on July 24 when conditions were almost the same. The green is stronger before 70° than subsequently; it was striking at 69° on a very clear night. On another night at 69° the hue decreased in intensity during a period of only 20 minutes. The results of twenty different observers favour the reality of the hues described above; but few observers see both the green and the brown, and some distinguish neither.

9. *Hercules.* $\lambda+39°, \beta+47°$. Sunrise 321°, noon 51°, sunset 141°. 21 observations.

Near 335° both Barcroft and I have thought the whole floor brown. Otherwise, the darker portions are brownish grey tinted by purple almost all lunation.

10. Humorum, Mare. $\lambda -40°, \beta -24°$. Sunrise 40°, noon 130°, sunset 220°. 2 observations.

On March 4, 1936, at 38° Roth and I suspected faint greenish tints on the terminator in this *mare*.

11. Julius Caesar. $\lambda +15°, \beta +9°$. Sunrise 345°, noon 75°, sunset 165°. 76 observations.

The conspicuous dark area at the north end is bluish or purplish, with a probable tint of brown, from sunrise until 150°. The south and east sides are grey tinged by brown from 350° to 140° unless perhaps grey between 55° and 90°. The remainder of the floor is greenish grey at sunrise, sensibly grey from 10° to 140°, and then a green that becomes intense by 160°. Cyrus states that he has frequently noticed the greenness of Julius Caesar.

12. Lichtenberg Area. $\lambda -67°, \beta +32°$. Sunrise 67°, noon 157°, sunset 247°. 4 observations.

On October 18, 1940, at 115° Barcroft observed a pronounced reddish brown or orange colour around this craterlet; he used three different eyepieces to guard himself against illusion. He found the colour less marked the next night at 127° and slight by October 22 at 163°. Has Barcroft recovered Maedler's reddish tint?[18]

13. Macrobius. $\lambda +46°, \beta +21°$. Sunrise 314°, noon 44°, sunset 134°. 2 observations.

Barcroft reports that on October 19, 1939, at 344° and on an unrecorded date about a year later the floor was reddish brown, a hue ordinarily absent.

14. Mersenius. $\lambda -49°, \beta -22°$. Sunrise 49°, noon 139°, sunset 229°. 40 observations.

The northeast part of the floor may be purple for at most a day just after sunrise. From 60° to 210° the darker portions are brownish grey, and after 220° the entire floor becomes very brown.

15. Phocydides. $\lambda -57°, \beta -53°$. Sunrise 57°, noon 147°, sunset 237°. 5 observations.

The floor is white at 190°. Toward sunset it grows darker and may be greenish after 225°.

16. Plato. $\lambda -9°, \beta +51°$. Sunrise 9°, noon 99°, sunset 189°. 154 observations.

The floor is greenish at sunrise except at the brownish east end, both hues soon lightening. From 40° to 160° Plato is greenish grey with the darker shadings (mentioned above) in it brownish grey. When these shadings fade out after 160° the floor assumes a peculiar green-brown tone, greenest at the east and brownest at the west. Note that under low illumination Plato is greenest next to the shadow and brownest at the opposite end.

Though necessarily based on my own observations, the cycle of changes just described is largely supported by the mostly very scattered work of twenty-two other observers. However, Buchanan concluded from observations on successive nights in the August-September, 1936, lunation that the green hue

deepens steadily from 27° to 138°. The high-sun brown tints were especially marked to Brockmeyer.

The greenness very probably changes irregularly. In 1938 I called the floor "least bit greenish" on May 17 at 123°, but "green" on July 15 at 124° under the same conditions. In 1937 the hue impressed me as "distinctly greenish" on July 22 at 79° but as "grey" on June 23 at 84°. Such variations are supported by Kaiser's remark (I translate):[22] "Although 90 observations are already present, it is still not possible to find any regularity in the appearance of this brown colour."

17. Ptolemy. $\lambda -2°$, $\beta -9°$. Sunrise 2°, noon 92°, sunset 182°. 21 observations.

The floor is dark green before 30° and after 140°, the intensity of the tint changing inversely as the sun's height. These results, obtained in 1938, do not agree with Kaiser's.[22]

18. Riccioli. $\lambda -74°$, $\beta -3°$. Sunrise 74°, noon 164°, sunset 254°. 115 observations.

The floor is probably greenish at sunrise but is no longer so by 90°.

The west edge of the dark area already described is grey before 85° and perhaps after 240° but is a peculiar purplish grey with a tinge of brown at all other times. The purple has been seen by six former Mount Union students in addition to me. Barcroft and a Mount Union student called the area brown, Martz thought the colour similar to that of Grimaldi, and two others noted only grey.

The colour of the dark area very probably exhibits irregular changes. Thus, in 1937 the colour was recorded as "deep purple" on September 28 at 191° and as "deep purple, hue vivid" the next night at 203°; but on July 2 at 195° I remarked merely "grey tinged by brownish purple." Conditions were very similar on all three dates.

19. Rocca Area. $\lambda -72°$, $\beta -13°$. Sunrise 72°, noon 162°, sunset 252° 81 observations.

The mark observed is a narrow and very dark area, thought to lie near Rocca, and readily located by prolonging a line from the north end of Gassendi A through the south end of Billy almost to the east limb. Grey at sunrise, this area is purplish from 100° until at least 240° except as it probably fades out after 140° in *some* lunations. It did so in several 1936 lunations; but in 1937, 1939, and 1940 no fading nearly so marked occurred before 190° except in one lunation or perhaps in two lunations. The intensity-changes of this area and their possible relation to libration are now being investigated.

20. Schickard. $\lambda -55°$, $\beta -45°$. Sunrise 55°, noon 145°, sunset 235°. 31 observations.

A very slight sunrise greenishness is gone no later than 73°; Cyrus has seen this hue, for he wrote me: "I saw green near the centre of the crater Schickard before the sun got too high over the crater." From 73° until about 200° the dark areas at the north and south ends are bluish grey or purplish grey, differing descriptions of one colour. At 190° a tinge of green reappears and has grown to dark green before sunset.

21. Stevinus. $\lambda+54°, \beta-32°$. Sunrise 306°, noon 36°, sunset 126°. 69 observations.

Martz and I have observed in a somewhat dark area south of Stevinus brown tints; these are present at 330°, most marked near 345°, and gone by about 15°. There may also be brownish areas on the floor of Stevinus during part of the lunation.

Final Remarks on Lunar Colours

When supplemented by a number of surveys of the whole moon that I made with colour-filters, the preceding discussion of lunar colours led to several conclusions:

1. Most lunar regions are sensibly white or neutral grey, according to their intensity, all lunation; such other colours as are present are slight, and even the most strongly coloured areas are about the same intensity when viewed with various colour-filters, evidence that their selective reflection of different wave-lengths is on a very small scale compared to that of the belts of Jupiter.

2. Low-sun colours are relatively striking but very transient, seldom being distinguishable between relative colongitudes 30° and 150°. The hues are usually greens, sometimes browns, and perhaps occasionally purples (or blues). Though infrequent even along the terminator, these colours affect chiefly very dark crater-floors very near that line.

3. High-sun colours are very inconspicuous but very stable, seldom changing appreciably between relative colongitudes 20° and 160°. The colours are blues (or purples) in the high-sun dark areas, especially the darkest ones; browns in delicate darker shadings on dark floors, the use of different filters having confirmed these browns to the extent of showing that some marks are redder than others; and greens over large dark areas, although greens more than 2 days from the terminator are very rare. Blue and brown are probably sometimes both present in the same area.

4. Some regions probably show irregular changes, both from lunation to lunation (Grimaldi) and over long periods of time (Lichtenberg).

Gruithuisen was apparently the first to make the natural suggestion that coloured areas represent lunar vegetation.[32, 33] This explanation might apply to high-sun hues but hardly to low-sun ones since the temperature is low near the terminator.[44] Though

aware that the data available are as yet too scanty to permit a satisfactory explanation to be deduced and tested, I should like to suggest that lunar colours and their changes may be due at least in part to chemical effects caused by the influence of the sun's heat and light on the surfaces of the moon's rocks.

Quantitative Aspects of Lunar Changes

The remarks in this section are based upon 17 surveys of the entire moon.

At sunrise all craters contain brightened east inner walls, which consist of bright terraces separated by rather dark regions. In the south hemisphere the brightest parts of such walls lie, on the average, south of east; in the north hemisphere they are, on the average, north of east. They thus tend to be precisely opposite the sun. West outer walls of craters and the west slopes of mountains ordinarily show less striking sunrise brightenings, perhaps because of a different slope. The preceding sentences will describe similar sunset brightenings if *east* and *west* are interchanged. The sunrise marks frequently dim greatly the first day in sunlight, and the sunset marks frequently brighten greatly the last day in sunlight. On the average east inner wall-areas are intensity 8 at sunrise, somewhat above 6 at relative colongitude 30°, and 5 at r.c. 150°, being shadowed soon after; shadowed until r.c. 30°, west inner wall-areas are 5 at that time, a little above 6 by r.c. 150°, and 8 at sunset.

Bright spots on north and south inner walls are usually about 5.5 all lunation. Near noon the brightest portions of inner walls are largely randomly distributed; but when in 1939 I investigated 7 craters at widely varying lunar latitudes to test for Pickering's reported rotation of the brightest areas on inner walls in attempting to keep always opposite the sun's position in the lunar sky,[62] I found some tendency for this rotation to occur.

Low-sun darkenings, which seldom cause marks to fall below intensity 2, affect chiefly crater-floors and *maria*. Darkened areas lighten rapidly the first 6 hours in sunlight and are almost "normal" 12 hours after sunrise; equally rapid darkenings occur near sunset. Marks bright most of the lunation are sometimes very briefly darkened at sunrise or sunset; perhaps we here have a penumbral

effect present when light is being received from only part of the sun's disc.

What may appropriately be called pseudo-shadows are almost universal on the moon. They are rather long-lasting; for craters fully 3, and sometimes even 5, days from the terminator regularly show darkened west (east) edges where shadow last was (first will be). The lightening (darkening) of these edges is so gradual that it is difficult to determine precisely when shadow leaves (enters) a crater. Less conspicuous pseudo-shadows are found on outer walls. Pseudo-shadows sometimes emulate the shapes of true shadows in a manner striking and puzzling, as we found when discussing the Theophilus peaks. After the shrinking (growing) sunrise (sunset) shadows (pseudo-shadows) have reached a certain size, they often lighten (darken) as unit areas. Pickering was misled by the forenoon pseudo-shadow in the crater Pickering when he reported shadow present almost until noon.[48]

I know no plausible explanation for these phenomena. One might ascribe those on inner walls to the sun's inability to illuminate properly the rough land there, but other pseudo-shadows cast on apparently level crater-floors and even on the relatively smooth *maria* behave in exactly the same manner as those on inner walls. The almost certain lack of any correlation of their behaviour with the sun's varying altitude in different lunar latitudes is averse to their being temperature-effects of any kind.

It is easy to find along the terminator neighbouring shadows that differ somewhat in darkness. Whether the lightest shadows are those which lie opposite the brightest inner walls, as we should expect if the difference is due to sunlight reflected into the shadows, is at present uncertain; the lack of such a relation would favour local lunar atmospheric effects as an explanation.

High-sun dark areas avoid the moon's polar regions, not being found beyond $\beta|\pm 45°|$, and are probably most common near the equator, a distribution found by Pickering also.[48,67] This condition suggests that the dark areas need certain temperatures to exist and is hence favourable to the vegetative explanation of them. They also avoid the relatively smooth *maria* except for the edges. In the southern hemisphere these areas are more numerous and darker in the south halves of crater-floors than in the north halves;

in the northern hemisphere the reverse is true. They thus prefer the half somewhat less well illuminated, a circumstance favouring the incident light explanation.

In the late afternoon the few dark areas still present are largely confined to the (less well lit) west halves of crater-floors; and near sunset long thin dark areas paralleling west rims and lying at the feet of west inner walls are common, such areas probably being due to the convexity of the moon's surface (as already mentioned). It is probable that the same appearances are present in the morning on the east halves of crater-floors.

The noon regions of the moon exhibit little contrast; most marks there are between 3 and 6 in intensity, and few are above 7 or below 2.

Some of the remarks in this section may be verified in Figure G on Plate XIV and on Plate XV.

Concerning Lunar Intensities

In the June-July, 1928, lunation Bennett took 11 photographs of the moon with a 3-inch aperture and selected for study on them 59 areas which were apparently smooth.[4] The intensity of each area on each plate that showed it in sunlight was measured with a densitometer, the region thus examined being 5 miles in diameter at the centre of the moon; and all measures were reduced to a scale where the mean surface brightness of the full moon was 100. The measures indicated that lunar areas have a strong tendency to reach maximum brightness at full moon. Bennett remarks that the brightness of a diffusely reflecting surface depends upon the reflecting power, the angle of incidence, the angle of reflection, and the angle between a plane through the normal and the incident ray and a plane through the normal and the reflected ray. He subjected these measures to a mathematical treatment and found that the intensity-changes are largely explained by assuming the presence of spherical pits on the moon's surface.[4]

In the years 1937, 1938, 1939, and 1940 I made 4,241 intensity-estimates of 131 marks scattered over much of the moon, each mark hence being estimated every 11 hours on the average. The estimates were made by comparisons at the telescope between the lunar marks and an artificial scale of graded intensities, the scale

being calibrated in the manner implied early in this paper (large shadows 0, etc.). Doubtless more accurate estimates could have been secured by projecting on the moon in the field of the eyepiece a light of controllable brightness and then by comparing lunar marks to this light; but I thought it well to obtain a comprehensive *qualitative* picture of lunar changes before attempting to get *quantitative* results by more refined methods, and it is pertinent to mention here that in 1938 Johnson and I estimated several marks in Atlas by different methods and secured results mostly pleasingly concordant.

In *any* study of lunar intensities, whether visual or photographic, and regardless of the techniques used, the following sources of observational errors must be watched for:

1. By diffusing the moon's light, haze sometimes gives rise to very false impressions of intensity.
2. The vibration of lunar detail attendant upon poor seeing mixes the light of adjoining areas and may in this fashion create erroneous impressions of intensity, an effect especially great for tiny marks contrasting greatly with their backgrounds.
3. A mark may not vary in intensity *as a unit*; an *integrated* impression of the brightness of its various parts is not desired but may be unintentionally obtained with minute marks, for example craterlets near the limit of visibility.
4. The lack of areas that may admissibly be supposed constant in intensity all their lunar days makes estimating less accurate and may cause large scale-errors.
5. To identify a mark with certainty under all illuminations is often not easy.

It is evident that the intensity-changes of a lunar area should be determined through estimates by one observer using one telescope at a fixed magnification and employing the same techniques for all estimates.

We next consider how intensity-variations supply information about the nature of the moon's surface and shall speak of "pits" for convenience. The disproportionate increase in the brightness of the moon toward the full phase shows that the lunar surface must contain many minute irregularities,[74] but whether it is actually pitted is uncertain. We shall make the simple assumption that the brightness of a lunar area depends only upon the amount of its *visible* surface (part of its surface may not be exposed to the line of sight) that is illuminated. The rough results we are ad-

ducing make it hardly worth while to introduce the sine of the sun's altitude above the area as a factor, though one should do so in order to take account of the fact that an area of given size is lit more intensely the less obliquely the sun's rays strike it. Our assumption implies that the lunar surface reflects light diffusely, a condition indicated by observation. Let us first consider a level surface, to which the line of sight is perpendicular, of constant albedo containing uniformly distributed hemispherical pits. The maximum brightness will evidently be reached at lunar noon; and this result will still apply if the pits are not hemispherical, for the shadows in them are smallest at noon. If the pits are shallow, there will be broad maxima of intensity and rapid changes when the shadows are shifting quickly under a very low sun; if the pits are deep, there will be sharp maxima and little change when the sun is low since the pits will be almost completely full of shadow for some time near sunrise and sunset. The range of variation in brightness will be determined by the amount of level surface intervening between pits. If either the line of sight or the axes of the pits are perpendicular to the surface, then maximum brightness will come at noon in the sense that the surface will never be brighter than at that time. If neither of the two is perpendicular, the surface will never be brighter than when the solar rays are incident parallel to the axes of the pits. If the pits are of different sizes and shapes and if the albedo of the surface is not everywhere the same, things to be expected in reality, no precise mathematical solution of the problem is feasible; nevertheless, the breadth of the maximum and the time(s) of rapid changes will indicate the depth of the pits relative to their size, the range of intensity-variation will suggest the relative amount of surface between pits, and the time of maximum will roughly reveal the direction of the axes of the pits.

(*To be continued*)

A QUOI SERT L'ASTRONOMIE?

Par J. Edgar Guimont

C'est grâce à l'astronomie si les anglais se rendent à leur colonie d'Australie plus facilement que les Phéniciens n'allaient à Carthage ou à Cadix.
(Cuvier.)

L'Astronomie est la sage fille d'une mère folle: l'astrologie.
(Philomaque.)

DEPUIS la plus lointaine antiquité, le mystère du ciel a exercé sur l'esprit de l'homme une légitime fascination.

L'Astronomie est probablement la plus ancienne de toutes les sciences. Elle a pris naissance le jour où les hommes ont contemplé le ciel et se sont posé, à la vue des étoiles et de leurs mouvements, une foule de questions demeurées sans réponses pendant de longs siècles.

Aujourd'hui, l'Astronomie a pris un tel développement, qu'elle embrasse toutes les sciences dans une vaste synthèse: elle est, à proprement parler, la science de l'univers visible; c'est elle qui nous fait connaître les corps célestes, le Soleil, la Lune, les étoiles, les comètes, en un mot tous les astres, leur constitution et les lois qui les régissent dans leurs mouvements.

C'est en observant les étoiles que les bergers Chaldéens ont acquis les premières notions d'un univers bien ordonné.

Pendant des siècles, les étoiles furent les seuls guides des navigateurs.

On ne soupçonne pas jusqu'à quel point l'Astronomie influence notre vie de tous les jours. Sait-on, par exemple, que les effluves magnétiques de notre Soleil, distant de 93,000,000 de milles, désorganisent parfois la diffusion par ondes courtes de la radio et troublent les images de la télévision?

A travers les espaces illimités, à l'aide d'instruments de plus en plus perfectionnés, les savants scrutent minitieusement les étoiles scintillantes et s'en font des laboratoires pour essayer de découvrir la composition intime des atômes et vérifier les expériences qu'ils font sur la terre.

En étudiant l'alliage si dur de fer et de nickel dont sont composés les météorites, les métallurgistes ont appris à fabriquer un acier plus résistant pour nos vaisseaux de guerre.

L'astronomie pilote les avions géants, les transports océaniques et les flottes de guerre. Elle règle nos horloges, trace les frontières internationales, précise les données géographiques évitant des conflits et facilitant de grandes entreprises commerciales ou industrielles. Ainsi, lors d'un aménagement hydro-électrique dans la vallée de la Gatineau, en octobre 1926, on a dû recourir aux levés géodésiques et aux observations astronomiques pour déterminer exactement la position des points choisis.

Nous nous rendons si bien compte aujourd'hui de l'importance de l'action solaire par exemple, qu'un certain nombre d'astronomes ont reçu pour fonction unique de surveiller minitieusement le disque enflammé, de le photographier, voire, de le cinématographier presque sans interruption et de mesurer les plus minimes variations de sa température.

En comparant l'éclat d'Arcturus, à la lumière chaude, et de Véga, à la lumière froide, on a eu l'idée de substituer aux anciennes ampoules électriques développant beaucoup de chaleur et dépensant beaucoup d'énergie, les ampoules à tungstènes lesquelles donnent un meilleur rendement tout en exigeant moins d'énergie et développant moins de chaleur.

"On sait que la géographie doit sa perfection actuelle aux progrès que l'astronomie a faits depuis environ cinquante ans et que, pour cette raison, les astronomes doivent être regardés comme les vrais géographes", . . . disait déjà LeGentil dès 1779.

L'observation des taches solaires nous permet d'édifier peu à peu les lois de la climatologie. Depuis plusieurs années le Dr. Charles G. Abbot, secrétaire de l'Institution Smithsonienne mesure les variations de la chaleur solaire. Il croit que ces taches sont la cause directe des variations de température sur la terre et que, si nos connaissances sur ce sujet étaient plus avancées, nous pourrions, deux semaines à l'avance, prédire le temps qu'il fera.

Petit à petit on apprend à utiliser l'énorme quantité d'énergie que le soleil nous envoie. On a inventé une machine mue par la chaleur du soleil concentrée au moyen d'un jeu de mirroirs. En Floride et en Californie, des habitations sont munies de systèmes à eau chaude fonctionnant par la chaleur du soleil.

La vitesse de la lumière fut découverte grâce aux perturbations périodiques des éclipses des satellites de Jupiter et cette vitesse

une fois connue, a servie à son tour pour la représentation des distances astrales.

L'éclipse se produit toutes les 42^h 28^m 36^s. On constate, à partir d'un certain point de l'espace, un retard dans chaque nouvelle éclipse, retard d'autant plus grand que le Terre s'éloigne davantage de Jupiter. Or, comme on connaît cet éloignement par des méthodes géométriques (parallaxes, etc.), on peut savoir la vitesse de la lumière.

Par l'analyse spectrale il est possible de reconnaître les corps dont les astres sont composés. Un astronome anglais, Lockyer, a même pu découvrir, en 1868, dans le spectre de la chromosphère du soleil, un gaz, l'hélium, dont on ne soupçonnait pas encore l'existence sur notre planète. Il ne fut découvert sur la Terre qu'en 1895, par William Ramsay.

L'analyse spectrale nous a encore permis de constater que tous les astres sont composés des mêmes éléments que la Terre.

Toutes les sciences ont bénéficié des observations et des découvertes faites en astronomie.

Mais quand l'homme, cessant pour un temps de se préoccuper de ce monde si agité, si boulversé, élève son regard vers la voûte céleste et qu'il se rend compte de l'immensité de l'Univers, oh! alors! il commence à se faire une idée de la grandeur de Dieu et comprend que le Créateur ait fait tout cela pour sa gloire.

En effet, songez que le rayon de notre système solaire est de près de 4 billions de milles (distance du Soleil à Pluton, la dernière planète, découverte le 18 février 1930 par Clyde Tombaugh); que la galaxie de la voie lactée, dont notre système solaire n'est qu'un détail, a quelque chose comme 600,000,000,000,000,000 de milles de diamètre; que la lumière prendrait 100,000 ans à la traverser.

La galaxie la plus voisine de la nôtre est la grande nébuleuse d'Andromède. La lumière qui nous en arrive voyage depuis 700,000 ans, et il y a dans l'espace *des millions* d'autres galaxies.

Cependant, dans tous ces grands univers, l'ordre règne. Tous ces corps se meuvent à des vitesses qui dépassent l'imagination: de l'ordre de 50,000 milles à la seconde. Et tous ces mouvements sont mathématiques. Les mêmes lois naturelles que l'homme a découvertes dans ses laboratoires gouvernent chaque atôme jusque dans la plus lointaine galaxie. "Ceci ne s'explique", dit le Dr.

Shapley, de Harvard, "que par la présence d'une intelligence de beaucoup supérieure à l'intelligence humaine."

Les trois jeunes hébreux, dans la fournaise, soupçonnaient-ils ces grandeurs quand ils chantaient: "Cieux, bénissez le Seigneur!" et que, dans un élan sublime, ils ajoutaient:

"*Espaces infinis* qui *êtes au-delà* des cieux, bénissez le Seigneur."

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Montreal.

REVIEW OF PUBLICATIONS

Yankee Stargazer, the Life of Nathaniel Bowditch, by Robert Elton Berry. 6½ x 9 ins., 234 pages New York, Whittlesey House, 1941. Price $2.50.

Among navigators, especially those of the United States, the name Bowditch is an everyday word. The standard manual of navigation published by the U.S. Hydrographic Office is the American Practical Navigator, by Bowditch. This book is a descendant of the volume which Nathaniel Bowditch brought out as the New American Practical Navigator in 1802.

Naturally, the radical changes introduced into the science of navigation by the universal use of chronometers and later of radio time service and direction finding, the development of the concept of position lines and circles, the St. Hilaire method of intercepts and tabular methods of solution have revolutionized the problem of astronomical navigation since Bowditch's time. Similarly steam and motor propulsion, gyrocompasses, improved logs and improved charts have forced the replacement of other part of the original handbook. However, the fact that Bowditch's name is still retained in this great manual is evidence of the influence he exerted on the art of navigation at a critical time in history.

It should be noted, however, that navigation was only one phase of Bowditch's remarkable career. He instructed himself in mathematics until, even in his youth, he was one of the distinguished mathematicians of his day in America. Despite the fact that he had only a few years of very elementary schooling, he received an honorary degree from Harvard at the age of twenty-nine, served as one of the Board of Overseers of the university, was offered professorships at Harvard, Virginia and West Point, and became president of the American Academy of Arts and Sciences. For many years he was president of an insurance company in Boston. His very thoroughly annotated and revised translation of Laplace's Mécanique Céleste was a task of many years and won him recognition by fellowship in the most learned societies throughout the world.

Fortunately there is abundant source material available on the life of Bowditch, starting from an excellent memoir by one of his sons, published in 1839 as a supplement to the last volume of Laplace. Mr. Berry has apparently carefully consulted them and written a very stimulating biography of this great American. The story of the boy's painstaking self-education, of his laborious copying out of hundreds of pages of mathematics from borrowed books, of his progress from a super-cargo on a sailing vessel to a position of highest respect in the economic and cultural life of the young republic, is told by the writer in a tale lightened by interesting anecdotes and notes on the time. It is a thoroughly enjoyable book.

F. S. H.

Weather and the Ocean of Air, by William H. Wenstrom. Boston, Houghton Mifflin Co., 1942. pp. 484, illus. Price $4.50.

This is perhaps one of the most useful books on the science of weather observation available for amateurs. It shows the reader how to construct a miniature weather observatory in his own home, how to interpret local weather signs, make accurate observations, and amuse himself by learning how difficult it is to make accurate weather forecasts even a few hours in advance. It will show him how to draw weather maps and may help him to read them intelligently.

The author of the book was closely connected with flights into the stratosphere, and the part of his book dealing with the exploration of the upper atmosphere is very interesting.

An air-minded generation will welcome this book, for it goes beyond the mere description of weather phenomena and attempts to initiate the reader in the modern mysteries of air-mass-and-front analysis. As this book is beautifully illustrated, it is not only entertaining and instructive, but also attractive.

When Wenstrom branches into the field of history it is better not to trust him, because here he is liable to be interesting rather than accurate. He repeats the radio commentator's fallacies about the rainy season in Poland that failed to stop Hitler. The reader should consult textbooks on history and climatology to safeguard himself against the acceptance of facile fallacies.

With this caution, I recommend the book heartily for the diversion of the amateur weather observer.

Alvin Thiessen.

Essentials of Astronomy, by John Charles Duncan. 181 pages, 5½ by 8½ in., with coloured frontispiece, 8 star maps on a blue background, and 87 figures in the text. N.Y. and London, Harper and Brothers, 1942. Price $1.85.

Professor Duncan is the author of a well-known textbook on Astronomy, now in its third edition, and in the present volume he aims to supply an elementary text suitable for a course which must be completed in a shorter time than a college year. This is done in 161 pages, every one of which exhibits the able astronmer, the experienced teacher and the accomplished writer.

The definitions are models of clearness and brevity, and there are some not usually found in larger treatises, e.g., barycentric parallax (p. 45). Indeed the condensation of so much into so small space may make the book rather hard for beginners, unless they have a live instructor. However these are the days of short courses with much crammed into them. The author does not evade mathematical statements. Here are to be found Kepler's Laws, Newton's Laws of Motion, with the geometric demonstration that if Kepler's law of areas is true the force must be central.

In chapter IV on Light is an excellent summary of the foundations of astrophysics. Then follow chapters on The sun's attendants, The sun and other stars, and Structure and action in the universe. The last paragraph is devoted to the red shift and its interpretation. The treatment and the facts given are up-to-date and one is pleased to see reproductions of a number of admirable photographs taken by Professor Duncan on his visits to Mount Wilson Observatory. At the end are 14 appendices containing interesting information.

C. A. C.

From Copernicus to Einstein, by Hans Reichenbach, translated by Ralph B. Winn. 113 pages, 6 by 9 inches. New York, Alliance Book Corporation, 1942. Price $2.00.

Einstein's Theory of Relativity has not been so prominently before the public in recent years, but it is firmly established in mathematical and physical philosophy. However it is still modern and not easy of comprehension. The author of this book attempts to give a straightforward account of the ideas and discoveries which led to the theory, and it can be said that he has been quite successful. The

various astronomical tests of the theory are well described, but that of the shift of the spectrum lines in a strong gravitation field lacks completeness.

The six chapters are: The Copernican view of the world, Ether, The special theory of relativity, The relativity of motion, General theory of relativity, Space and time. There are eleven diagrams, some of which are rather crude, and yet they assist the argument. The book is not 'popular', but being written in a clear manner it will clarify the intelligent reader's thoughts on mathematical philosophy.

C. A. C.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

DEATH OF CAPT. EVERALL.

William Montgomery Everall died at Victoria, B.C., on June 18, 1942. He was born November 29, 1873, in Guatemala City, Central America, where his father was a coffee planter and British consul. His mother was a Scotswoman named Montgomery. He was educated in England, was an electrical engineer with the P. & O. Company and in 1902 became chief electrical engineer of the Hong Kong Power Co. After spending six years in China he came to Canada in 1908 and was a construction engineer with the Canadian National Railways. Then he was appointed to the Dominion Government Works Department at Port Arhtur and was such until 1914 when he was commissioned an officer in the Cycle Corps and almost immediately went to France from which in 1917 he was invalided back to Port Arthur. Next year he was transferred to Victoria where he remained with the Dominion Public Works Department until his retirement in 1934.

On the outbreak of the present war Capt. Everall tried to enlist and in October 1941 was appointed to a position in the naval service, Esquimalt. He was a member of the R.A.S.C. for many years and was first vice-president of the Victoria Centre at the time of his death.

C. A. C.

An Eighteen Inch Reflector Available

Mr. Gordon Shaw, a former president of the Victoria Centre, has written about the disposal of an eighteen-inch Gregorian type reflector built by the late Mr. H. Hodgkinson of New Westminster, B.C. Mr. Hodgkinson was an enthusiastic amateur, and a very good mechanic. He had made about twenty mirrors, of which this was his final achievement. Mr. Shaw, an optometrist and himself a skilled telescope maker, has observed with this telescope, and considers it excellent. The telescope is equatorially mounted with setting circles. The tube is of wood and metal construction. Mrs. Hodgkinson is anxious to dispose of this instrument at a very reasonable price. Anyone interested should communicate with Mr. Shaw (Woolworth Building, Victoria, B.C.) for further particulars.

F. S. H.

Victoria Summer Course in Astronomy

Members of the Council and of the Society have long been interested in the progressive and successful work of the Victoria Centre in its annual Summer Course in Astronomy. The following editorial from the Victoria Daily Colonist (July 30, 1942) shows that the Press and public of Victoria appreciate this finely organised service.

IS WELCOME FEATURE

Victoria Centre of the Royal Astronomical Society of Canada is to continue its popular series of "Summer Evenings Under the Stars," now entering the eleventh year. A series of first-class talks on astronomy, field observations with small telescopes, and a visit to the seventy-two-inch reflector telescope at Little Saanich Mountain are included in an attractive programme under the society's direction. Continuation of the feature will be welcomed.

The lectures, which will open to members, and to those who on payment of a very nominal fee wish to attend them, will be held at Victoria College, commencing on August 3. Dr. R. M. Petrie, Dr. K. O. Wright and Dr. Andrew McKellar, of the Dominion Astro-Physical Observatory staff, once more are contributing to the success of the lecture series; while the observatory, under Dr. J. A. Pearce, director, is placing its facilities at the disposal of the group.

There are few features of the Summer season in Victoria that have drawn more appreciative attention, or which have contributed more interestingly to the pleasure of residents and visitors alike. The course this year is so designed that it is in effect an introduction to the heavens for those who have not had time before to become acquainted with their wonders. The subject is a compelling one. Each year the series of "Summer Evenings Under the Stars" introduces larger numbers of people to the inexpressible beauty of the night-time skies.

F. S. H.

MEETINGS OF THE SOCIETY

AT WINNIPEG

March 10, 1942.—The regular meeting was held in Theatre "F", University Buildings. The president, Mr. L. W. Koser, was in the chair.

The first speaker was Mr. L. T. S. Norris-Elye, who showed fine slides and photographs to illustrate his talk on the surface of the moon. The craters in some cases are so wide as to be like walled plains. The mountains at the rim are precipitous and higher in proportion than many of the earth's mountains. The huge cracks reaching for miles seem to be filled with dark lava and in some cases pass through craters and mountains. Wargentin crater itself is almost level to the brim with lava. As the mountain peaks are very sharp, almost like spires, the lack of erosion seems evident. In several instances debris can be noticed which would fill a space left in the nearby mountains. In Triesnecker, Pickering once said that he saw a landslide, but this statement was never substantiated.

The second speaker was Mr. G. P. Morse, who spoke on "Early Mathematics relating to Astronomy." He commenced by showing how duplation (the forerunner of multiplication) was done about 900-1300 A.D. The Greeks were great theorists and geometers but were not as practical as the Egyptians who used knotted ropes to lay out grounds of uniform size. This gave rise to our square measure of area. The Egyptian priests used the noon shadow as a reference in determining the hours of labour, and as early as 1680 B.C. the solstice shadows at Stonehenge were marked. Later a little more calculation gave a true east-west line and the properties of a right-angled triangle were discovered. Some of the pyramids were built with a passage in line with the lower culmination of the then pole star and another passage in line with the culmination of Sirius.

About 600 B.C. Thales, a visitor from Greece, discovered how to use shadows to estimate the height of the Great Pyramid. About 250 B.C. Eratosthenes used the difference in length of the noon shadows at places 500 miles apart to calculate the size of the earth's circumference, which he stated to be about 24,000 miles. The mariners at this time believed the earth to be a sphere as they had noted several lunar eclipses. Hipparchus calculated the distance to the moon to be a quarter of a million miles. Ptolemy gave us the plane and spherical geometry tables.

The Chaldeans were the first perhaps to use the circle as symbolic of the year. The radius of the same circle cut it into a six-sided figure whose angles could be bisected again to give twelve angles for the twelve signs of the Zodiac. This gave the inaccuracy of 360 days in a year. This error was known as early as 4000 B.C. in Egypt when they used the number of days intervening between two successive occasions when Sirus was just visible at its setting

immediately before sunrise. Reference was also made to the pyramids in Yucatan.

Discussion ended a most interesting evening.

OLIVE A. ARMSTRONG.

April 8, 1942.—The regular meeting was held in Theatre F, University of Manitoba. The president, Mr. L. W. Koser, was in the chair.

The topic of Mr. W. P. Johnson's address was "The Vision of the Human Eye".

The ether spectrum was first discussed and the attention of the audience drawn to the fact that only a small part was visible to the human eye. The anatomy of the eye was next reviewed and some facts that are not so well known were given. On the retina of the eye the nerve ends take the shape of rods and cones. The rods give the sensations of size, shape and light or dark greys while the cones, fewer in number, provide the sensations of colour. The rods are able to see stars of about the fifth or sixth magnitude, while the cones can see only to the third or fourth magnitude—hence the lack of variety in colour of the fainter stars. A deficiency of these cones causes colour-blindness. This is many times more prevalent among men than women.

A purplish fluid at the back of the eye is flooded across the nerve ends when a sudden bright light is seen. This bleaches out with the light when the lens has been adjusted.

The range of vision shrinks when it includes coloured objects and of course the centre of our vision is the most dependable. Lenses were used to show aberration and refraction and the irregularities of short and long sight and astigmatism were discussed.

Demonstrations with much elaborate apparatus were given to show:

(1) Absorption of light by a colloidal solution (30 c.c. hyposulphate of soda, 10 c.c. hydrochloric acid in about 2 gal. of water). (2) Absorption of light by filters. (3) Different colours given off by burning different metal salts. (4) Polarized light by tourmaline crystals.

A sound film, "Curves of Colour", was shown at the conclusion. The lecture was ably given and much appreciated.

OLIVE A. ARMSTRONG.

AT VICTORIA

October 8, 1941.—The first meeting of the Fall Session of the Society was at 8.10 p.m. in the lecture hall of Victoria College, with the President, Dr. R. M. Petrie, in the chair. Four members were received as a result of the Summer Course: C. H. Summers, E. P. Stocker, Corp. C. Yarwood, and Miss H. R. Staghall. The librarian, Miss Hailstone, told of interesting articles published in "The Sky" and invited members to borrow copies from her at the close of the meeting; and Mr. Peters gave a very informative description of the autumn sky. The president then introduced the Director of the Dominion Astrophysical Observatory, Dr. J. A. Pearce, as the speaker of the evening.

Dr. Pearce had chosen for his subject, "Some Applications of Radial Velocities" as they were developed and adapted at the Observatory. He first quoted the beliefs of Bruno, Hooke and Halley concerning the motions of the stars and the first proof by Maskelyne in 1783 that seven stars had definitely moved relative to others in the heavens. Just 100 years ago Doppler stated his famous principle on which our ideas of radial velocities are based. This was modified in 1848 by Fizeau, though not published until 1870 and the formula $dv/c = d\lambda/\lambda$ is now familiar to all students of the subject. Sir William Huggins was the first real astrophysicist as he combined laboratory and observatory; and in 1868 he showed how to measure radial velocities of the stars. The first spectrogram was taken by Vogel in 1899. The apparatus has been somewhat modified until we now have the modern spectrographs and measuring equipment at the D.A.O. which were illustrated on the screen.

By means of examples the various corrections to be applied to observed stellar velocities as well as the many applications of these results were very lucidly explained. These included the radial velocities of the planets applied to their motion about the sun, their rotation period and the composition of the rings of Saturn; the radial velocities of double stars and the changing orbits of spectrographic biraries. The stream motions of individual stars, which shows their membership in moving clusters; convection in stellar atmospheres; the motions of the constituent matter in interstellar atmospheres; the motions of the constituent matter in interstellar clouds; the solar motion and galactic rotation, have all been studied at the Observatory and the methods were made to appear simple by the clear exposition of the lecturer.

K. O. Wright, *Recorder.*

October 29, 1941.—The President, Dr. R. M. Petrie, called the meeting to order at 8.15 p.m. Application for membership in the Society from Mr. A. G. Day was received and approved. The librarian, Miss C. Hailstone, called attention of members to the new location of the library at the College; and Mr. Gordon Shaw announced that the eight-inch Springfield-mounting telescope loaned to the Centre by Mr. Reid had been received and that the Council were considering where it should be mounted.

In introducing the speaker of the evening, the President told how Mr. W. H. Stilwell had studied for two years at Berkeley, which is world-renowned as the present centre of theoretical astronomy, before coming to Victoria to join the staff of the D.A.O. The Centre was fortunate in having Mr. Stilwell speak to them on "The Earth as an Astronomical Body". The earth was first compared with the stars; the former is solid, faint, small and light, whereas the latter are gaseous, bright, large and heavy, and it appears that a planet is more unusual in the universe than a star. The speaker went on to mention the physical characteristics of the earth—its dimensions, heat and atmosphere—and gave details of the Joly-Cavendish experiment for measuring the mass of the earth. The diurnal motion of the earth was then considered and the proofs of its rotation: the Foucault pendulum experiment, the deviation of projectiles and the anti-clockwise motion of cyclones. The annual motion of the earth is

shown by motion of the constellations, the annual parallax of stars, the aberration of light and the Doppler shift of spectrum lines. The lecturer concluded by explaining the earth's motion in space, best known as the Solar Motion.

Many questions were submitted to the lecturer which included remarks concerning the roughness of the earth's surface, the reason for the present composition of the atmosphere, and the unknown composition of the earth's interior.

K. O. WRIGHT, *Recorder.*

November 19, 1941.—The meeting was called to order at 8.10 p.m. with the President, Dr. R. M. Petrie, in the chair. Mr. Herbert R. Davis was elected a member of the Society; announcement concerning the Annual Dinner on December 13 was made; and Miss Hailstone, the librarian, mentioned briefly Mr. Brydon's article on "Solar and Sidereal Time" in Popular Astronomy. Mr. J. G. Buehler then gave a talk on "The Progression of the Zodiac" in which he stated that the present Piscian Age is one dominated by sorrow and oppression of the weak, but the Aquarian Age will soon begin when electrical achievements will dominate the course of mankind. In a brief reply, Mr. Peters mentioned that Ceres and Vesta were nearer than Jupiter and Saturn and thus errors in astrological reasoning might well creep in.

The speaker of the evening, Mr. W. R. Hobday, had long been active in the affairs of the Society and no introduction was needed before the President called upon him to talk on "The Vault of the Heavens". Mr. Hobday first told how two classes of people would probably be interested in our Society: those who desired to learn about the sky, the constellations and the objects of interest from the sense of their artistic value; and those to whom a knowledge of the principles of astronomy was indispensable. A very elementary treatment of the subjects desired by each class was to be attempted this evening. A brief description of the physical conditions and features of the moon, sun and planets was given by Mr. Hobday and then a number of slides were shown: the phases of the moon, the sizes and orbits of the planets, the sizes of the stars, the winter constellations, the Milky Way and the spiral nebulae.

Following the lecture, a number of questions were asked the speaker, and Dr. C. S. Beals told about the modern interpretation of the dark patches in the Milky Way.

K. O. WRIGHT, *Recorder.*

January 28, 1942.—The meeting was called to order by the President, Dr. R. M. Petrie, at 8.10 p.m.

Mr. Edison W. Adshead and Mrs. Catherine M. Adshead were elected to membership in the Society by acclamation.

The president mentioned the general gratification of the Centre in the presentation of the Chant Medal to Mr. H. Boyd Brydon.

Dr. K. O. Wright had been given charge of the arrangements for a trip to the Dominion Astrophysical Observatory for members of the Society, in order to view the planets Jupiter, Saturn and Mars, now so well placed for observation. He specified February 7, 9, or 10, as suitable evenings, and arranged

with the Committee of the last Annual Dinner to get into telephone communication with members, the night clear at 4 p.m. being chosen, and Blue Line Bus used.

The president then called on the speaker of the evening, Mr. Gordon Shaw, who had chosen "Light, Lenses and Mirrors" as his subject. Mr. Shaw began by admitting that the exact nature of light is still a mystery, and not really understood. It could be defined as radiant energy. Newton had proposed a theory known as the Corpuscular Theory, in which he thought particles were emitted by a radiant body. Huygens' theory was that a subtle medium, the ether, was disturbed by waves emitted by the radiant body; and his theory is known as the Wave Theory. The latter theory almost superseded the former, but neither is quite stable today.

The speaker went on to consider the properties of light, its intensity and velocity. Bright sunlight, he stated, is equivalent to 10,000 candles per square foot. The very high velocity of light was first obtained by Roemer, by observing the eclipses of Jupiter's satellities. This result was a splendid approximation to the true value. The lecturer next described reflection and its laws, and showed how plane and spherical mirrors formed images. Then passing to refraction, he gave Snell's law and showed how a lens might be considered as a series of prisms. In philosophic mood, Mr. Shaw mused how a piece of glass was used to correct the vision of the young and add years to the eyes of the aged, formed the microscope, telescope, camera, spectroscope, and moving pictures. In such uses the piece of glass had profoundly influenced humanity.

ROBERT PETERS, *Recorder.*

February 18, 1942.—The meeting was called to order at 8.15 p.m. by the President, Dr. R. M. Petrie. Miss Hailstone, the librarian, told of the memoirs concerning the late Dr. J. S. Plaskett which have recently been published and also issued a plea to the membership for an additional book-case to contain our expanding library. The recent trip to the D.A.O. for views of the planets was described by Dr. Wright. Then followed the presentation of the 1941 Chant Medal to H. Boyd Brydon as described in the March issue of the JOURNAL. Dr. Petrie and Mr. Gordon Shaw fittingly described the merit of our candidate and expressed great pleasure that his efforts had been recognized, after which Mr. Brydon made a brief reply in which he exhorted everyone to bend every effort to bring another Chant Medal to Victoria.

Lieut.-Commander H. R. Tingley gave the address of the evening on the subject "Ships and Stars". Commander Tingley explained that navigation is still not an exact science and he could not claim to be the expert which Dr. Petrie had claimed for him. He described briefly the early history of navigation as pursued by the Chinese, Phoenicians, Egyptians and Greeks in which the mariners went from island to island, and if beyond sight of land their course was pure guesswork. Commercial navigation began shortly after the satellites of Mars and he gave the periods, which were similar to those discovered much later.

Miss Langworthy, the second speaker, took Jupiter as her part in the sym-

Crusades, when the Portuguese, French, English, Dutch and Spaniards vied with each other for the shipping routes of the known world. Henry of Portugal first used the astrolabe and also made up the first table of declinations, which greatly helped the Portuguese to determine latitude. The speaker told of the various routes which could be followed from place to place: in the earliest scientific method one sailed to the correct latitude of the destination and then went east or west until it was sighted; in the rhumb line method the true bearing remains a constant angle and Mercator's projection of the earth is most useful; and finally the great circle route is used to-day because it is the shortest distance between two ports. Commander Tingley described how Harrison, the Yorkshire watchmaker, won the Admiralty prize for the determination of longitude by producing the modern chronometer; how Sumner with his "line" was able to determine his correct position by means of two "sights" with his sextant; and how St. Hilaire modified Sumner's method to perfect the method for determining positions at sea as they are determined to-day. The speaker closed his talk by giving a practical application of St. Hilaire's method and also showed how to use a sextant.

K. O. WRIGHT for *Recorder.*

March 11, 1942.—The meeting was called to order by the President, Dr. R. M. Petrie. Mr. Dodwell was nominated for membership and elected by acclamation. The librarian, Miss Hailstone, reviewed the book, "Earth, Moon and Planets" by F. L. Whipple, in which she noted a table giving the positions of the major planets, monthly, until 1970.

Mr. Gordon Shaw reported that a home had been found for the Reid telescope; Mr. H. R. Day, of Tattersal Dr., had offered a site on the grounds of his home. He stated that there was a fine horizon in this high location. The recorder moved, and Mr. Shaw seconded, a motion that Mr. Day be thanked for his very liberal offer and this was carried with applause.

The programme of the evening was a symposium by three lady members of the Council, Miss C. Hailstone, Miss Y. Langworthy and Miss M. Oliphant, who had chosen the subject "The Wandering Worlds".

The first speaker was Miss Hailstone, who sketched the place of the Solar System giving the sizes, distance and other particulars of the members from Mercury to Pluto. There followed a brief discussion on the position of the sun in the cosmos, surrounded by an infinitude of sister suns. At this point, Miss Hailstone paused and, with dramatic effect asked: "How does this appeal to you? We are in a world, of a system, in a galaxy among a million galaxies."

The planet Mars was described in detail and mention made of the observations of Schiaparelli who noticed apparent grooves or channels which he called "canali", but the English word "canals" took root firmly. Lowell's work was commented on and his pictures of Mars shown, with others obtained at Mount Wilson and Flagstaff Observatories. The remarkable passage in Swift's "Gulliver's Travels" was mentioned, in which Swift stated that there were two posium. The great size of the planet was emphasized, the general "lightness" compared with the earth was noted, and the suggestion made that the central

core was surmounted by a very thick layer of ice, perhaps thousands of miles thick, then a very extensive atmosphere composed largely of methane and ammonia. The very low temperature would make the planet uninhabitable for any forms of life which we know. The satellites, of which there are eleven, were noted and 8, 9 and 11 were stated to revolve in a retrograde direction; the others are direct. The discovery of the velocity of light by Roemer in 1675 by observing the eclipses of the Galilean satellites was perhaps an indirect link in the chain that led to the discovery of radio. For practical purposes, the speaker concluded, we compare Jupiter with the earth but we should think of it rather in terms of contrast than comparison. Jupiter is a very different world from ours, inhumanly strange, cold and remote.

Miss Oliphant, the secretary, described Saturn, to complete the symposium. She traced the history of the planet from Galileo to Cassini. The strange "handles" observed by Galileo were proved to be rings, and Cassini noted the divisions. The markings, size and weight were commented on, and the extensive system of satellites was reviewed. Saturn is the lightest of the planets and would float on water if an ocean of sufficient size could be found for the experiment.

In the general discussion which followed, Dr. Petrie stated that the components of the atmosphere of Mars are unknown; we know some gases which are not there, but almost nothing of what is present.

ROBERT PETERS, *Recorder.*

April 1, 1942.—Dr. K. O. Wright called the meeting to order, owing to the indisposition of the president. Miss Hailstone, the librarian, reviewed "Between the Planets" by Fletcher G. Watson, another in the series of Harvard Books on Astronomy which had recently been purchased by the Centre. The recorder briefly mentioned the large sun spots, the interesting proximity of Jupiter and Mars and also the difficulties in printing the 1942 edition of the Nautical Almanac after the plates had been destroyed.

The lecture of the evening was "The Changing Stars" by Mrs. Phoebe Noble, B.A. Mrs. Noble, the former secretary of the Centre, divided the variable stars into five classes: temporary stars or novae; long period variables with periods from 50 to 600 days of which Mira, o Ceti, is a type; irregular variables, such as alpha Herculis or Betelgeuse; Cepheid variables; and eclipsing variables such as Algol.

The lecturer elaborated on each class and gave interesting particulars concerning Nova Aquilae which increased to 60,000 times its former brightness in a few hours, only to relapse again into inconspicuousness. Mira, "the wonderful star," was commented upon and its strange cycle traced. Much information was also given on Algol, the "demon star" of Perseus, and the history of this object formed a fascinating section of Mrs. Noble's lecture. The Cepheids were treated to a careful study and it was shown how a simple method of obtaining stellar distances could be derived from their periods, and how this could be used to determine distance of clusters and nebulae.

ROBERT PETERS, *Recorder.*

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1890-1942

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For many years the Toronto organization existed alone, but now the Society is national in extent, having active Centres in Montreal, P.Q.; Ottawa, Toronto, Hamilton and London, Ontario.; Winnipeg, Man.; Edmonton, Alta.; Vancouver and Victoria, B.C. As well as about 700 members of these Canadian Centres, there are over 200 members not attached to any Centre, mostly resident in other nations, while some 300 additional institutions or persons are on the regular mailing list for our publications.

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